Fast Simulation tools for ILC physics studies

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Snowmass Energy Frontier Workshop, BNL , Apr 2013

Outline

The ILC is not LHC

- Lepton-collider: Initial state is known.
- Production is EW $\Rightarrow$
  - Small theoretical uncertainties.
  - No "underpaying event".
  - Low cross-sections wrt. LHC, also for background.
  - Trigger-less operation.
  - High precision (sub-%) measurements needed, to extend our knowledge beyond LEP, Tevatron, LHC.
  - Interesting physics at low angles: t-channel di-boson production ...
- Extremely small beam-spot: 5 nm $\times$ 100 nm $\times$ 150 μm.
- High luminosity: 2×10^{34} cm^{-2} s^{-1}. Single pass operation $\Rightarrow$ this is the lumi for every bunch-crossing.

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- Small beam-spot ⇒ Beam-beam interactions ⇒
  - Large amounts of synchrotron photons, that get Compton back-scattered.
  - They might create e^+e^- pairs when interacting with the field: The pairs-background.
  - Or interact with each other: mini-jets
- Single pass operation, ondulator positron-source, beam-beam effects: Beam-spectrum is not a δ-function.
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The ILC : Detectors

- Low background ⇒ detectors can be:
  - Thin : few % X_0 in front of calorimeters
  - Very close to IP: first layer of VXD at 1.5 cm.
  - Close to 4π: holes for beam-pipe only few cm = 0.2 msr un-covered = Area of Suisse Romande (or Schleswig-Holstein or Connecticut) relative to earth.
- High precision measurements:
  - Extremely high demands on tracking.
  - Tracking to low angles
  - Identify and measure every particle in the event = Particle-flow:
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Fast simulation types, and the choice for ILC

Different types, with increasing level of sophistication:

- 4-vector smearing. Ex. SimpleFastMCProcessor.
- Parametric. Ex.: SIMDET, Delphes
- Covariance matrix machines. Ex.: LiCToy, org.lcsim fastMC, SGV

Common for all:

Detector simulation time $\approx$ time to generate event by an efficient generator like PYTHIA 6

For ILC:

Only Covariance matrix machines have sufficient detail. Here, I'll cover "la Simulation à Grande Vitesse", SGV. (For org.lcsim fastMC, see Norman's talk on Tuesday)

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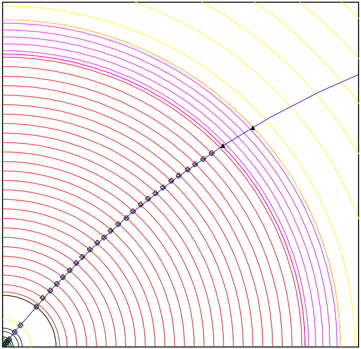
SGV: How tracking works

SGV is a machine to calculate covariance matrices

Tracking: Follow track-helix through the detector.



- Calculate cov. mat. at perigee, including material, measurement errors and extrapolation. NB: this is exactly what Your track fit does!
- Smear perigee parameters (Choleski decomposition: takes all correlations into account)
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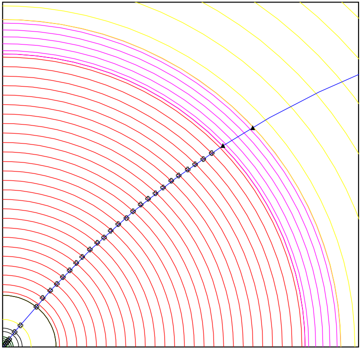

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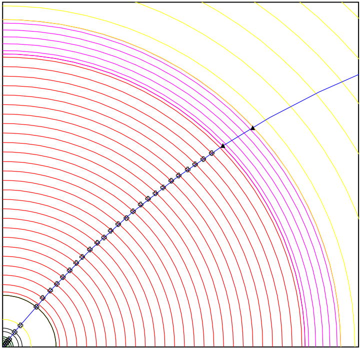

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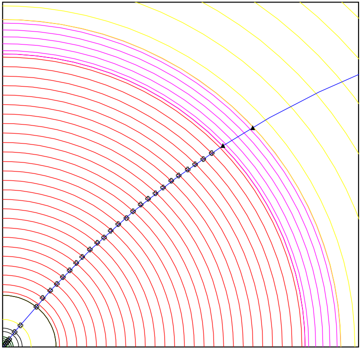

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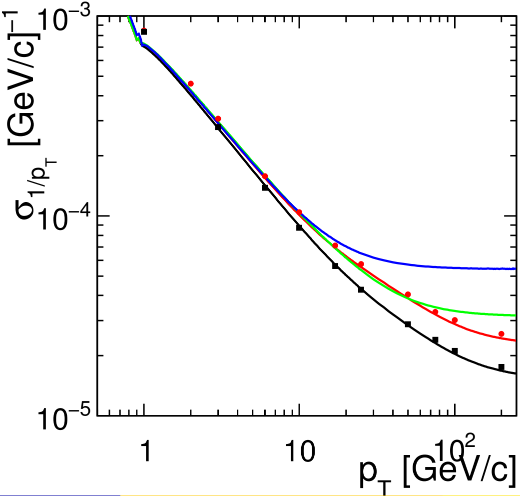
SGV and FullSim LDC/ILD: momentum resolution

Lines: SGV, dots: Mokka+Marlin



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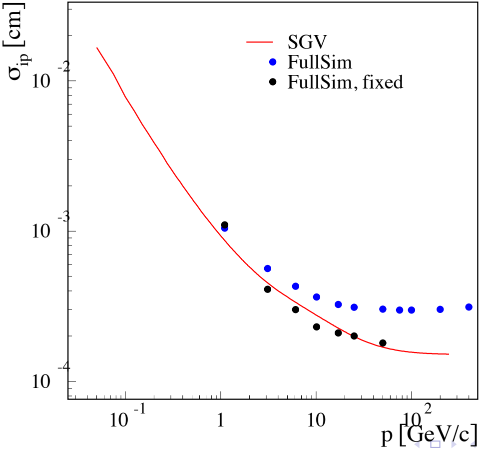

SGV: How the rest works

Calorimeters:

- Follow particle to intersection with calorimeters. Simulate:
  - Response type: MIP, EM-shower, hadronic shower, below threshold, etc.
  - Simulate single particle response from parameters.
  - Easy to plug in other (more sophisticated) shower-simulation. Next slides.

Other stuff:

- EM-interactions in detector material simulated
- Plug-ins for particle identification, track-finding efficiencies,...
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Calorimeter simulation

The issues:

- Clearly: Random E, shower position, shower shape.
- But also association errors:
  - Clusters might merge.
  - Clusters might split.
  - Clusters might get wrongly associated to tracks.
- Will depend on Energy, on distance to neighbour, on EM or hadronic, on Barrel or forward, ...
- Consequences:
  - If a (part of) a neutral cluster associated to track $\rightarrow$ Energy is lost.
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Parametrisation

Look at how PFA on FullSim has associated tracks and clusters: link MCParticle -> Track and/or true cluster -> Seen cluster.

- Identify and factorise:
  1. Probability to split
  2. If split, probability to split off/merge the entire cluster.
  3. If split, but not 100 %: Form of the p.d.f. of the fraction split off.
- All cases (EM/had - split/merge - Barrel/endcap) can be described by the same functional shapes.
- Functions are combinations of exponentials and lines.
- 28 parameters $\times$ 4 cases (em/had $\times$ double-counting/loss)

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Checking the parametrisation

Feed exactly the same physics events through FullSim or SGV.

- Overall:
  - Total seen energy
- $e^+e^- \to ZZ \to$ four jets:
  - Reconstructed M_Z at different stages in FullSim.
  - Seen Reconstructed M_Z, FullSim and SGV.
  - Jet-Energy resoulution
- *Zhh* at 1 TeV:
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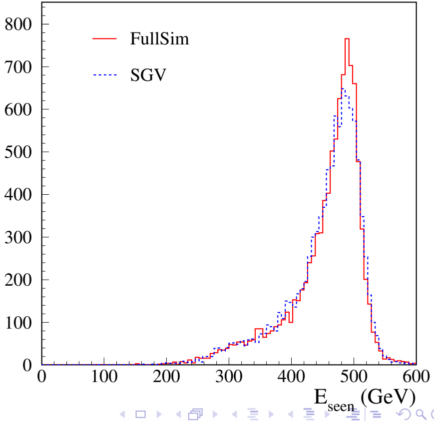

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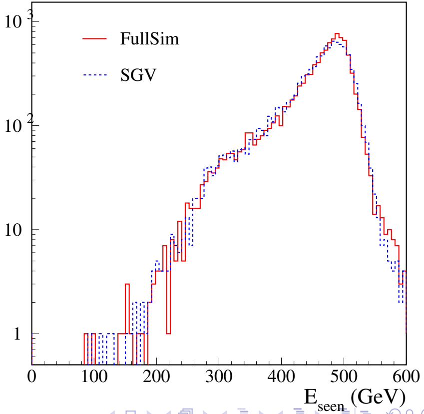

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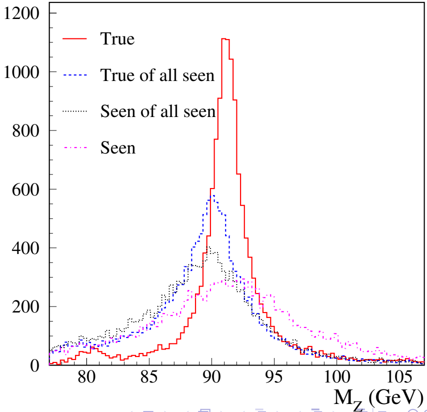

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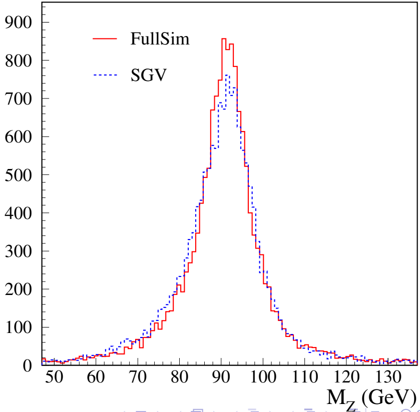

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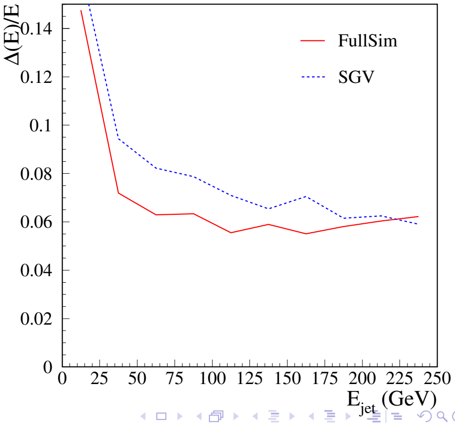

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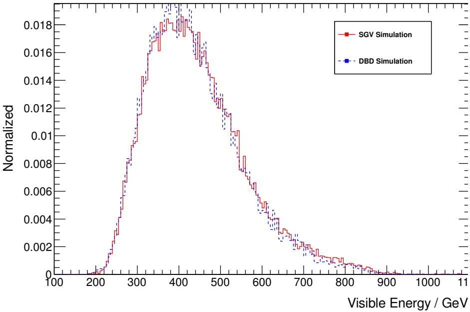

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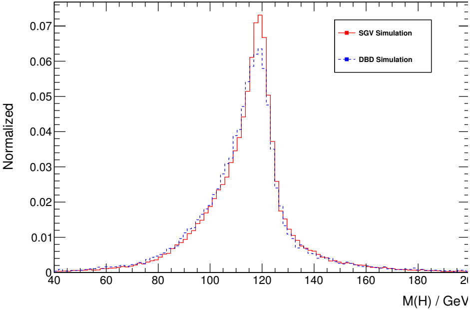

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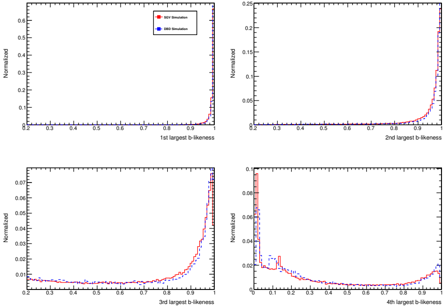

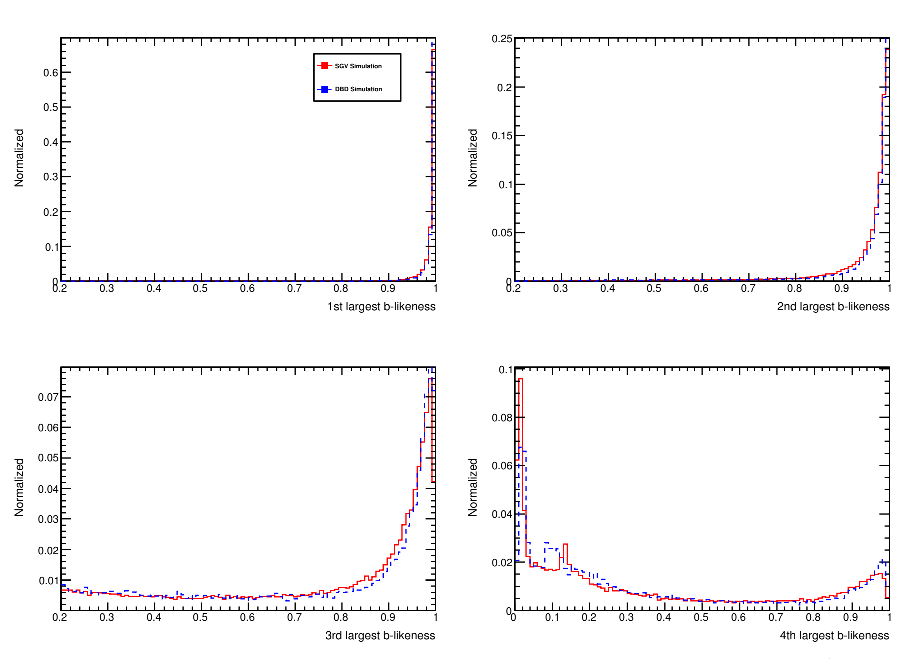
SGV Simulation
DBD Simulation
Normalized
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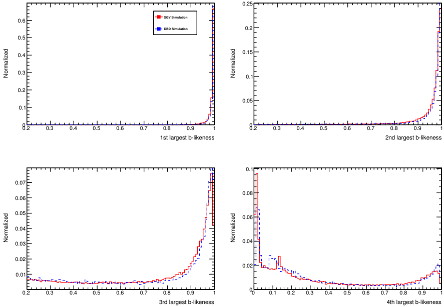

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- Some CERNLIB dependence. Much reduced wrt. old F77 version, mostly by using Fortran 95's built-in matrix algebra.
- Managed in SVN.Install script included.
- Features:
  - Callable PYTHIA, Whizard.
  - Input from PYJETS or stdhep.
  - Output of generated event to PYJETS or stdhep.
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  - Development on calorimeters (see later)
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LCIO DST mass-production

SGV has been used to produce ILD LCIO DST:s for the full DBD benchmarks- several times.

- 43 Mevents.
- $\sim$ 1 hour of wall-clock time (first submit to last completed) on the German NAF.
- On the grid under:
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    - (xxx= 2f, 4f, ... , zzz= 1000-B1b_ws, 500-TDR_ws, ... (y is 6 right now. Always use the latest !)

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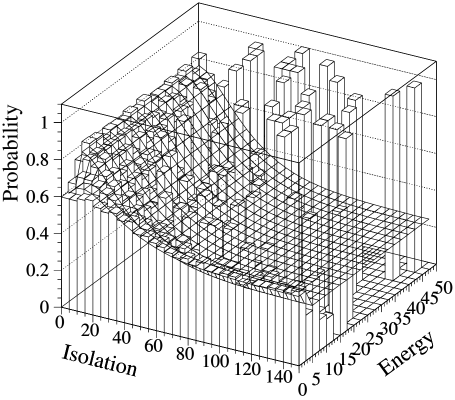
Thank You !

Backup

BACKUP SLIDES

Observed distributions

- Probability to split (charged had or γ)
- Fraction the energy vs distance
- ... and vs E
- Fit of the Distribution of the fraction
- Average fraction vs. E and distance.



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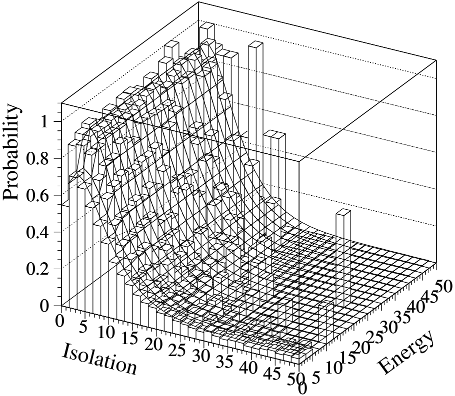

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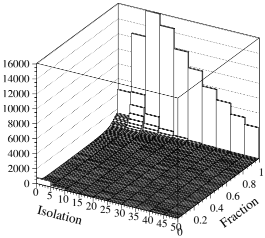

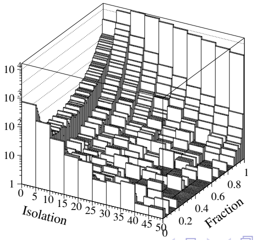

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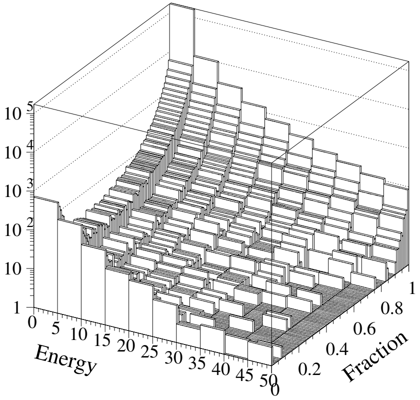

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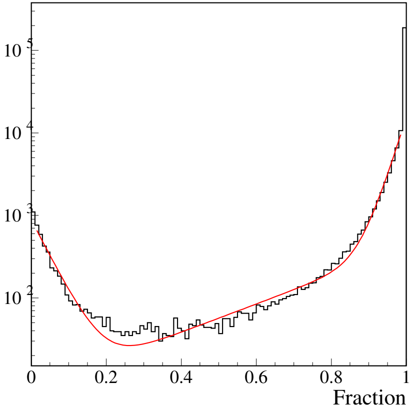

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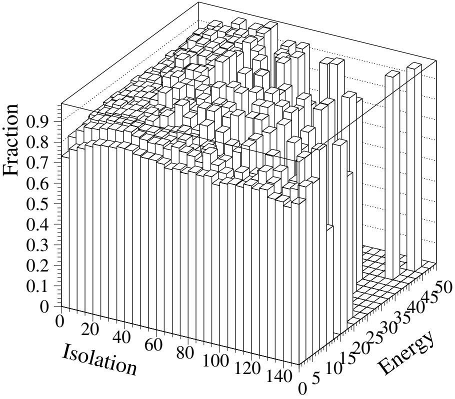

$\gamma\gamma$ background

Total cross-section for $e^+e^- \rightarrow \gamma\gamma e^+e^- \rightarrow q\bar{q}e^+e^-$: 35 nb (PYTHIA)

- $\int \mathcal{L}dt$ = 500 fb^{-1} $\rightarrow$ 18 $\star 10^9$ events are expected.
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10^8 s of CPU time is needed, ie more than 3 years. But:This goes to 3000 years with full simulation.

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SUSY parameter scans

Simple example:

- MSUGRA: 4 parameters + sign of μ
- Scan each in eg. 20 steps
- Eg. 5000 events per point (modest requirement: in sps1a' almost 1 million SUSY events are expected for 500 fb^{-1} !)
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Use-cases at the ILC

- Used for fastsim physics studies, eg. arXiv:hep-ph/0510088, arXiv:hep-ph/0508247, arXiv:hep-ph/0406010, arXiv:hep-ph/9911345 and arXiv:hep-ph/9911344.
- Used for flavour-tagging training.
- Used for overall detector optimisation, see Eg. Vienna ECFA WS (2007), See Ilcagenda > Conference and Workshops > 2005 > ECFA Vienna Tracking
- GLD/LDC merging and LOI, see eg. Ilcagenda > Detector Design & Physics Studies > Detector Design Concepts > ILD > ILD Workshop > ILD Meeting, Cambridge > Agenda >Sub-detector Optimisation I

The latter two: Use the Covariance machine to get analytical expressions for performance (ie. *not* simulation)

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Calorimeter simulation: SGV strategy

- Concentrate on what really matters:
  - True charged particles splitting off (a part of) their shower: double-counting.
  - True neutral particles merging (a part of) their shower with charged particles: enetgy loss.
- Don't care about neutral-neutral or charged-charged merging.
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Collections

- Added sensible values to all collections that will (probably) be there on the DST from the fullSim production.
  - BuildUpVertex
  - BuildUpVertex_RP
  - MarlinTrkTracks
  - PandoraClusters
  - PandoraPFOs
  - PrimaryVertex
  - RecoMCTruthLink
  - MCParticlesSkimmed
  - V0Vertices
  - V0RecoParticles
  - BCALParticles
  - BCALClusters
  - BCALMCTruthLink
  - PrimaryVertex_RP
- Also added more relation links:
  - MCTruthRecoLink
  - ClusterMCTruthLink
  - MCTruthClusterLink
  - MCTruthTrackLink
  - TrackMCTruthLink
  - MCTruthBcalLink

Comments

Secondary vertices (as before):

- Use true information to find all secondary vertices.
- For all vertices with ≥ 2 seen charged tracks: do vertex fit.
- Concequence:
  - Vertex *finding* is too good.
  - Vertex *quality* should be comparable to FullSim.

In addition: Decide from parent pdg-code if it goes into BuildUpVertex or V0Vertices !

MCParticle :

- There might be some issues with history codes in the earlier part of the event (initial beam-particles, 94-objects, ...)

Comments

Clusters:

- Are done with the Pandora confusion parametrisation on.
- Expect $\sim$ correct dispersion of jet energy, but a few % to high central value.
- See my talk three weeks ago.
- Warning: Clusters are always only in one detector , so don't use E_{had}/E_{EM} for e/π: It will be $\equiv$ 100 % efficient !

Navigators

- All the navigators that the TruthLinker processor makes when all flags are switched on are created:
  - Both Seen to True and True to Seen (weights are different !)
  - Seen is both PFOs, tracks and clusters.
  - The standard RecoMCTruthLink collection is as it would be from FullSim ie. weights between 0 and 1.

Outlook

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  - Use of user-defined types.
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- The Grid.
- Investigate running on GPU:s.
- Further reduce CERNLIB dependence - at a the cost of backward

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  - In the last case: output STDHEP of event
- Update documentation and in-line comments, to reflect new structure.
- Consolidate use of Fortran 95/203/2008 features. Possibly - when gcc/gfortran 4.4 (ie. Fortran 2003) is common-place - Object Orientation, if there is no performance penalty.
  - Use of user-defined types.
  - Use of PURE and ELEMENTAL routines,
  - Optimal choice between pointer, allocatable and automatic and/or assumed-size, assumed-shape, and explicit arrays.
- I/O over FIFO:s to avoid storage and I/O rate limitations.
- The Grid.
- Investigate running on GPU:s.

Outlook

- Include a filter-mode:
  - Generate event inside SGV.
  - Run SGV detector simulation and analysis.
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- Investigate running on GPU:s.
- Further reduce CERNLIB dependence - at a the cost of backward